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FOR

HEAD FOR RECORDING AND READING OPTICAL DATA AND METHOD OF MANUFACTURING THE SAME

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HEAD FOR RECORDING AND READING OPTICAL DATA AND METHOD OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

Field of the Invention:

The invention relates generally to a head for recording/reading optical data and method of manufacturing the same, and more particularly to, a head for recording /reading optical data and method of manufacturing the same capable of improving throughput of a laser beam passing through apertures in order to record/read data in a probe type mode (AFM mode) (Atomic Force Microscopy) and a NSOM (Near-Field Scanning Optical Microscopy) mode.

Description of the Prior Art:

In order to store more information per unit area in an optical storage device, it is required that the wavelength of a recording optical source be reduced or the numerical aperture of a condensing lens must be increased. To satisfy such a requirement, it may be considered to develop a blue laser diode (LD) and to increase the numeral aperture up to 1.0. In these cases, however, there is a limit that information is recorded with a high density due to diffraction of light, in a next generation information storage device requiring a high-density recording.

As an option for overcoming this limit, there are a SPR (Scanning

Probe Recording) technology using a probe of AFM (Atomic Force Microscope), an ultra-resolution medium technology, a technology using a Near-Field Scanning Optical Microscopy (NSOM) probe that overcomes the diffraction limit of light and the like.

As a first example of a prior art, a technology using a NSOM optical fiber probe employs a laser light outputted to an aperture having a very small size (aperture: several dozens ~ several hundreds of nm). In case of the NSOM optical fiber probe, however, it is mechanically very fragile and is not easy to arrange it in plurality at a time. Further, as throughput of light outputted to the aperture is very small (generally about $10^{-5} \sim 10^{-7}$ in cases of an aperture having 100nm in size), the NSOM optical fiber probe is very difficult to be actually used in view of recording and data processing speed.

In other words, in order to use the NSOM optical fiber probe in an optical storage device, an aperture having a high throughput is required and a probe arranged in plurality and not easily abraded mechanically is required.

A second example of a prior art has a probe having a plurality of apertures through a semiconductor process (Fig. 1).

Referring now to Fig. 1, there are formed a plurality of holders **11** are provided. Probes **12** formed of a thin metal film are formed at the bottom of the holders **11**. Apertures **13** are formed between the probes **12**. Even in this case, however, as transmissivity of a laser beam outputted from the apertures **13** of the probes **12** is below 10^{-5} as in conventional optical fiber probe, it is required that transmissivity be increased. A method of improving throughput of light transmitted into a hole at an end portion of the probes **12**

includes a method of exciting plasmon, a method of minimizing an optical loss region generated from one wavelength size at the end portion, etc.

The third example of a prior art attempted to improve throughput of the aperture by a method of exciting plasmon. Plasmon Mode, however, it is difficult to effectively excite plasmon since its exciting efficiency depends on the polarization of an incident beam. In order to more effectively excite plasmon, there is a need for an aperture structure by which plasmon can be effectively excited through a special process.

A fourth example of a prior art include a method of making an aperture structure having a high throughput by making an end portion of the probe minimize an optical loss region. The method of minimizing the optical loss region, that is a method introduced in a conventional optical fiber probe, makes the aperture having a very large cone angle through a multi-step wet etching process. A reflection film for reflecting an incident light is located in a first taper region and a reflection film having a very large cone angle is located in a second taper region, so that the optical loss region can be reduced by maximum. Also, a very small aperture having a probe shape is positioned in a third taper region to form an aperture of high throughput. In this case, however, as the size of the aperture representing an optimum high throughput is defined depending on the first taper region and the aperture is manufactured by a multi-step wet etch process, there is a problem that its manufacturing process is complicated. Further, there is a problem that it could not be applied to an optical storage device of a probe mode since the end portion of the probe is very large.

Meanwhile, a fifth example of a prior art includes a method of manufacturing an aperture of a high throughput using semiconductor process and wet etch process. The method manufactures a probe the end portion of which has a parabolic structure of a very large cone angle through anisotropic etching process to silicon, a low-temperature oxide film formation process, a deposition process of Cr and a wet etching process in order to minimize the optical loss region. In case of this structure, however, as the process of manufacturing the probe including the low-temperature oxide film formation process is complicate, there is a problem that it is difficult to make the end portion of the probe in a parabolic shape.

The conventional arts so far attempted to improve throughput by making an actual object. However, there is a method by which a method similar to a method of manufacturing the aperture having a large cone angle is applied to a semiconductor process conceptually.

Referring now to Fig. 2, a sixth example of a prior art will be explained. A relatively large aperture (1 micron to 2 micron) is formed by a silicon semiconductor process and a reflection film is coated, where this structure corresponds to the first taper region mentioned in the fourth example of a prior art. At this time, a hole having a very small size (60nm) is formed at the center of the reflection film to form an aperture of a high throughput. At this time, a non-linear thin film is additionally coated on the reflection film and self-focusing being a non-linear characteristic is generated through the non-linear thin film, thus additionally improving the optical throughput of the aperture.

However, this method includes first forming a reflection film in the first taper region and then forming an aperture in the reflection film to form the aperture of a high throughput. However, this method is almost impossible to be used. The reason is that a mode of light reflected by the reflection film could not be effectively transferred to a mode existing in the aperture using only the first reflection film. Also, in this case, there is a region having a large light loss same to a conventional optical fiber probe. Further, though a thin film for causing self-focusing is additionally coated on the reflection film, there actually occurs no any self-focusing phenomenon. The reason is that the refractive index varies spatially in an already-formed structure since the refractive index is spatially different depending on the non-linear characteristic. Due to this, the difference in the phase delay is spatially generated to change the size and shape of beam, so that the amount of beam can be increased since a defocusing phenomenon not self-focusing can be generated. In other words, as the structure in which the non-linear thin film is coated on the reflection film has a limit to reduce the amount of beam (about one wavelength), throughput of light is not so increased. Further, this structure has a structure in which the end portion of the probe is very flat not a probe shape structure. Therefore, there is a problem that this structure could not be applied to an optical storage device using the probe mode though it could be simultaneously applied to the probe mode and the near-field scanning optical microscopy.

SUMMARY OF THE INVENTION

The present invention is contrived to solve these problems and an object of the present invention is to provide a head for recording/reproducing optical data that generates self focusing and in which an aperture is fully filled with a material having a three dimension non-linear coefficient, and method of manufacturing the same, which can reduce the amount of beam by about half wavelength, focus beam in a parabolic shape having almost no optical loss to effectively excite a near-field scanning optical microscopy to the aperture at an end portion of a probe and improve the throughput of the probe than several hundreds times than a conventional optical fiber probe.

In order to accomplish the above object, a head for recording/reading optical data according to the present invention is characterized in that it comprises a plurality of apertures formed in a silicon deposition layer an end portion of which is connected to a silicon substrate, a plurality of probes formed at the bottom of the silicon deposition layer at a region where the plurality of the apertures are formed, and a non-linear material buried within the plurality of the apertures.

A head for recording/reading optical data according to another embodiment of the present invention is characterized in that it comprises a silicon layer an end portion of which is connected to a silicon substrate and the bottom of which has a probe shape, a plurality of apertures formed in the silicon layer of the probe shape, a thin metal film formed on the silicon layer including the plurality of the apertures, and a non-linear material buried within

the plurality of the apertures.

A method of manufacturing a head for recording/reading optical data according to another embodiment of the present invention is characterized in that it comprises the steps of providing a silicon substrate on which a silicon oxide film and a silicon deposition layer are stacked; etching the bottom of the silicon substrate by a given depth to form an opening; forming an aperture having a given slant angle in the silicon deposition layer located on the opening; forming a prove in the silicon deposition layer around the aperture exposed through the opening; and burying the aperture with a non-linear material.

The non-linear material generates a self-focusing phenomenon and is made of a material a third non-linear coefficient of which is very great. The non-linear material is made of As_2S_3 and is buried at the temperature of about 120℃.

The present invention discloses a head for recording/reading optical data having an aperture of a high transmissivity by which an optical throughput of a probe necessary to record and reproduce optical data is improved by over 100 times compared to a conventional optical fiber probe using a self-focusing phenomenon, and method of manufacturing the same.

Further, the present invention can manufacture an aperture throughput of which is improved, by effectively optically inducing its effect through a simple semiconductor process without mechanically changing a structure of a probe end portion through a multi-step semiconductor process as in a prior art, in order to improve throughput. In addition, the present invention can

manufacture an aperture of a high throughput that can be arranged in plurality.

Additionally, the aperture the throughput of which is improved using a self-focusing phenomenon can be applied in manufacturing a probe type near-field scanning optical microscopy that is arranged in plurality. The aperture can also be applied to a probe type head where a dielectric material film is formed in the aperture and a thin metal film is then formed on the dielectric material film. Therefore, the present invention can be applied both to a probe type mode (AFM mode: Atomic Force Microscopy) and a NSOM (Near-Field Scanning Optical Microscopy) mode.

BRIEF DESCRIPTION OF THE DRAWINGS

The aforementioned aspects and other features of the present invention will be explained in the following description, taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a cross-sectional view of a probe having a plurality of apertures;

Fig. 2 is a cross-sectional view of a conventional near-field scanning optical microscopy (NSOM) optical head;

Fig. 3 is a perspective view of a head for recording/reproducing optical data according to the present invention;

Fig. 4a to Fig. 4i are cross-sectional views for explaining a method of manufacturing a head for recording/reproducing optical data according to the present invention;

Fig. 5 shows a state showing a self-focusing phenomenon generated within apertures in which a non-linear material is buried;

Fig. 6 is a characteristic graph illustrating the throughput depending on the size of the apertures;

Fig. 7 is a perspective view of a head for recording/reproducing optical data according to another embodiment of the present invention; and

Fig. 8a to Fig. 8g are cross-sectional views for explaining a method of manufacturing a head for recording/reproducing optical data according to another embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention will be described in detail by way of a preferred embodiment with reference to accompanying drawings, in which like reference numerals are used to identify the same or similar parts.

Fig. 3 is a perspective view of a head for recording/reproducing optical data according to the present invention.

Referring now to Fig. 3, the head for recording/reading optical data is mainly divided into two sections: a lower structure and an upper structure. The lower structure includes a silicon substrate **21** and finally becomes a holder of the head. The upper structure has a reverse-trapezoid shape and includes a probe having a plurality of apertures **25** filled with a non-linear material **28** and a thin metal film **27**, wherein an end portion of the probe is connected to the lower structure.

The upper structure further includes a silicon deposition layer **23**. A silicon oxide film **22** is formed at the boundary of the lower structure and the upper structure. A plurality of the probes having the thin metal film **27** are formed at the bottom of the upper structure. A portion of the non-linear material **28** filled in the aperture **25** of a reverse-trapezoid shape by etching process, formed in the silicon de position layer **23**, is exposed toward the bottom of the silicon deposition layer **23** included in the upper structure.

A method of manufacturing the head for recording/reproducing optical data will be below described.

Figs. 4a through 4i are cross-sectional views for explaining a method of manufacturing the head for recording/reproducing optical data according to the present invention, which shows a process of manufacturing the head for recording/reproducing optical data taken along lines **X-X'** in Fig. 3 step by step.

Referring now to Fig. 4a, a silicon oxide film **22** is formed on a silicon substrate **21**. Then, silicon is deposited on the silicon oxide film **22** to form a silicon deposition layer **23**. First and second nitride films **24a** and **24b** are formed at the bottom of the silicon substrate **21** and the top of the silicon deposition layer **23**. Next, the first nitride film **24a** formed at the bottom of the silicon substrate **21** is patterned to expose a given portion of the bottom of the silicon substrate **21**. At this time, the width of the exposed silicon substrate **21** is $1 \sim 10mm^2$.

In the above, it should be understood that a silicon oxide film or a silicon nitride film might be used instead of the nitride film.

Referring now to Fig. 4b, the bottom of the exposed silicon substrate **21** is etched by a first etch process. The bottom of the silicon substrate **21** is etched in about 100 ~ 1000 μm and an oblique plane **21a** becomes (111) of silicon.

The first etch process is performed with a wet etch, by which a given thickness of the silicon substrate **21** remains from the silicon oxide film **22**. This is to physically protect the silicon deposition layer **23** since the thickness of the silicon deposition layer **23** is relatively thinly formed than the thickness of the silicon substrate **21**.

Referring now to Fig. 4c, the second nitride film **24b** formed on the top of the silicon deposition layer **23** is patterned to expose a given region of the silicon deposition layer **23**. Then, a second etch process is performed to form a plurality of apertures **25** (only one is shown in the drawing).

At this time, the second etch process is performed with a wet etch. The aperture **25** has a reverse-trapezoid shape by a recipe of the second etch process. The silicon oxide film **22** is exposed at the bottom of the aperture **25**. At this time, etching is performed at the bottom of the silicon substrate **21** where the first nitride film **24a** is not formed, so that the remaining silicon substrate is removed and the bottom of the silicon oxide film **22** is exposed. Thus, the silicon substrate **21** is divided centering on the aperture **25**.

A lower base of the aperture **25** is 10 ~ 100nm in size and the top of the aperture **25** is 1 μm ~ 100 μm in size. At this time, the depth of the aperture **25** functioning as a waveguide is 1 μm ~ 10 μm.

Referring now to Fig. 4d, the first and second nitride films **24a** and

24b and the silicon oxide film **22** exposed at the bottom of the silicon substrate **21** are removed.

Referring to Fig. 4e, a dielectric film **26** is formed on the silicon deposition layer **23** including the aperture **25**. The dielectric film **26** is formed to be a pattern through which a given region of the silicon deposition layer **23** between the aperture **25** and another aperture (not shown) is exposed.

Referring now to Fig. 4f, the exposed portion of the bottom of the silicon deposition layer **23** is removed by a given thickness by means of an etch process. The top of the silicon deposition layer **23** is not etched by the dielectric film **26**. The silicon deposition layer **23** at a region between the aperture **25** where the dielectric film **26** is not formed and another aperture (not shown) is completely etched/removed. At this time, the dielectric film **26** formed in the aperture **25** is not etched to have a reverse-trapezoid shape intact.

Referring now to Fig. 4g, a thin metal film **27** is formed on both the bottoms of the silicon deposition layer **23** and the dielectric film **26**. Thus, a probe consisting of the thin metal film **27** is formed.

The thin metal film **27** is formed to overcome the diffraction limit optically and is formed using aluminum in thickness of about 100nm.

Referring now to Fig. 4h, a non-linear material **28** is buried into the aperture **25**.

The non-linear material **28** is a material that can generate a self-focusing phenomenon and is made of a material a third non-linear coefficient of which is very great. The material that is great in a third non-linear

coefficient includes AS_2S_3. The temperature when the aperture **25** is filled with AS_2S_3 is about 120℃. At this time, as beam could not be self-focused by about one wavelength size if the aperture **25** is not completely buried when the non-linear material **28** is buried, the aperture **25** is completely buried with the non-linear material **28**.

Referring now to Fig. 4i, the silicon substrate **21**, the silicon oxide film **22** on the silicon substrate **21**, the silicon deposition layer **23** and the dielectric film **26**, at one side, are removed. Thus, the head for recording/reproducing optical data shown in Fig. 3 is completed.

The shape of beam reaching around the aperture **25** of about below 100nm in size formed in the silicon deposition layer **23** by the above process is determined by the amount of beam, the intensity of an incident beam and the amount of a third non-linear coefficient. In order to form the aperture **25** having a high transmissivity, it is required that the shape of beam reaching around the aperture **25** have a shape having a parabolic structure the cone angle of which is very large.

Fig. 5 shows a state showing a self-focusing phenomenon generated within apertures in which a non-linear material is buried.

Referring now to Fig. 5, the aperture **25** filled with a non-linear material **28**, the beam reaching a lower base of the aperture **25** is incident at an angle of θ f greater than θ and has a parabolic structure having a very large cone angle. Also, it could be seen that the amount of beam has about half wavelength. Therefore, the aperture **25** can have a high throughput that is improved by several hundreds times than the throughput of a conventional

optical fiber probe.

As a result, in order to improve the throughput of the aperture **25**, the beam reaching a lower base of the aperture **25** must be incident in a parabolic structure having a very large cone angle, as shown in Fig. 5.

Fig. 6 is a characteristic graph illustrating the throughput depending on the size of the apertures.

Referring now to Fig. 6, it could be seen that the throughput of the aperture is improved by over several hundreds times by the calculated throughput.

Fig. 7 is a perspective view of a head for recording/reproducing optical data according to another embodiment of the present invention; and

Referring now to Fig. 7, a head for recording/reproducing optical data is mainly divided into two sections; a lower structure and an upper structure. The lower structure includes a silicon substrate **61** and finally becomes a holder of the head. The upper structure includes a plurality of aperture **65** filled with a non-linear material **68** having a reverse-trapezoid shape. The bottom of the upper structure has a probe structure and actually functions as a probe **63a** and the end portion of the upper structure is connected to the lower structure.

As in Fig. 3, the upper structure further includes a silicon deposition layer **63**. A silicon oxide film **62** is formed at the boundary of the lower structure and the upper structure. A part of the non-linear material 68 buried in the aperture **65** of a reverse-trapezoid shape, formed in the silicon deposition layer **63** by an etch process, is exposed toward the bottom of the

silicon deposition layer **63** in the upper structure. The difference from the head for recording/reproducing optical data shown in Fig. 3, is that additional probe need not be formed using a thin metal film since the bottom of the silicon deposition layer **63** is formed to be a probe type shape by an etch process. As a result, as the silicon deposition layer **63** functioning as the holder of the probe functions as a probe, the holder of the probe and the probe are integrally formed.

A method of manufacturing the head for recording/reproducing optical data will be below described.

Figs. 8a through 8g are cross-sectional views for explaining a method of manufacturing the head for recording/reproducing optical data according to another embodiment of the present invention, which shows a process of manufacturing the head for recording/reproducing optical data taken along lines **Y-Y'** in Fig. 7 step by step.

Processes shown in Figs. 8a through 8d are same those shown in Fig. 4a to Fig. 4e. Thus, the explanation will be omitted for the purpose of simplicity.

Referring now to Fig. 8e, a portion exposed at the bottom of the silicon deposition layer **63** is removed by a given thickness by means of an etch process, wherein the bottom of the silicon deposition layer **63** is etched along the slant angle of the aperture **65** while a portion where the aperture **65** is formed has a given thickness. Thereby, a probe **63a** including the silicon deposition layer **63** of a given thickness is formed at the bottom of the aperture **65**.

At this time, the top of the silicon deposition layer **63** is not etched by a dielectric film **66**, and the silicon deposition layer **63** at a region between the aperture **65**, where the dielectric film **66** is not formed, and another aperture is completely removed.

Referring now to Fig. 8f, a thin metal film **67** is formed on the dielectric film **66** including the region where the aperture **65** is formed. Next, the aperture **65** is completely filled with a non-linear material **68**.

The thin metal film **67** is formed to further improve the throughput of the aperture **65** and is formed in thickness of about 100nm using aluminum.

The non-linear material **68** is a material that can generate a self-focusing phenomenon and is made of a material a third non-linear coefficient of which is very great, as described with respect to Fig. 4h. For example, the aperture **65** is completely buried using AS_2S_3 that maintains the temperature of about 120℃ and is great in the third non-linear coefficient. At this time, as beam could not be self-focused by about one wavelength size if the aperture **65** is not completely buried when the non-linear material **68** is buried, the aperture **65** is completely buried with the non-linear material **68**.

Referring now to Fig. 8g, the silicon substrate **61**, the silicon oxide film **62** on the silicon substrate **61**, the silicon deposition layer **63** and the dielectric film **66**, at one side, are removed. Thus, the head for recording/reproducing optical data shown in Fig. 7 is completed.

Similarly, the shape of beam reaching around the aperture **65** of about below 100nm in size formed in the silicon deposition layer **63** by the above process is determined by the amount of beam, the intensity of an incident

beam and the amount of a third non-linear coefficient.

As mentioned above, the present invention has advantages that it can improve the transmissivity by burying an aperture with a non-linear material and can record/read optical data at a high speed using apertures arranged in plurality. For example, if the size of the aperture is about 50nm, the recording density may be several Giga bit/inch^2, which surpasses a current information storage capacity. Also, the aperture of a high throughput can be used for physical properties of a high resolution as well as a head of a high-density optical information storage device and the like.

The present invention has been described with reference to a particular embodiment in connection with a particular application. Those having ordinary skill in the art and access to the teachings of the present invention will recognize additional modifications and applications within the scope thereof.

It is therefore intended by the appended claims to cover any and all such applications, modifications, and embodiments within the scope of the present invention.